The Genera Globigerina and Globorotalia in the Paleocene-Lower Eocene Lizard Springs Formation of Trinidad, B.W.I.

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Introduction

Authors of previous papers on the foraminiferal fauna of the Lizard Springs formation restricted their observations entirely to surface sections. Because of complex tectonic conditions in Central and South Trinidad, most of the Lizard Springs outcrops are small isolated slipmasses that are often confined to a single zone and therefore are not suitable for comprehensive stratigraphic and evolutionary studies. The Lizard Springs formation as encountered in wells often consists of similar slipmasses. In a few boreholes, however, continuous and apparently undisturbed sections of over 1,000 feet in thickness have been penetrated. These sections, combined with surface information, now allow a much more complete and reliable study of the foraminiferal species and their stratigraphic ranges than was previously possible.

Although the planktonic Foraminifera are strongly predominant in many samples of the Lizard Springs formation, not much attention was paid to them until Bronnimann's paper on the Globigerinidae appeared in 1952. The usefulness of planktonic Foraminifera for zoning has already been proved in older and younger sediments (Upper Cretaceous, Eocene-Miocene). The present study of *Globigerina* and *Globorotalia* shows that a similar pattern of comparatively short ranges for most species also prevails in the Paleocene-lower Eocene Lizard Springs formation of Trinidad.

On the basis of benthonic Foraminifera, the Lizard Springs formation was previously subdivided into a lower and an upper zone. The stratigraphic distribution of the planktonic Foraminifera in the more complete sections now available allows eight well-defined zones to be distinguished, five of which are regarded as of Paleocene age (lower Lizard Springs) and three as of lower Eocene age (upper Lizard Springs). As a rule the fauna of the basal part of the Lizard Springs formation is entirely arenaceous. The arenaceous Lizard Springs facies, which is given zonule rank, may however also occur in higher parts of the Paleocene portion of the Lizard Springs formation. Beds almost indistinguishable from this facies may possibly also replace part of the calcareous Upper Cretaceous Guayaguayare formation. Furthermore it is a time and facies equivalent of the Chaudiere formation of the Central Range.

Preliminary examination of Paleocene and lower Eocene samples from widely separated regions such as Venezuela, the United States Gulf Coast area, Peru, North Africa, and Europe suggests that a zonation of the Paleocene-lower Eocene on the basis of planktonic Foraminifera can be a useful tool for interregional correlation.

Stratigraphy

For the history and earlier zonation of the Lizard Springs formation, reference is made to Cushman and Renz (1946). On the basis of benthonic smaller Foraminifera, these authors subdivided the formation into a lower and upper zone and a probable late Maestrichtian to Danian age was suggested for both. A short account of a subsequent controversy on the Cretaceous age of the Lizard Springs formation was given by Bolli (1952), who regarded the age as Paleocene. Bronnimann (1952) maintained the subdivision of the formation into a lower and upper zone, both of Paleocene age.

These authors restricted their observations on the Lizard Springs formation to the type locality as described by Cushman and Renz, and to a few other surface samples. The type locality represents a slipmass within a synorogenic clay-boulder bed of Miocene age. It was already stressed by Cushman and Renz that this section, measuring about 250 feet, is strongly disturbed and incomplete. Other Lizard Springs outcrops in central and south Trinidad have the same shortcomings and often consist of only a single zone. Similar conditions were previously mentioned for Upper Cretaceous sediments (Bolli, 1956). It is therefore fortunate that there is available a number of carefully recorded favorable subsurface profiles which allow the study of fairly continuous sections of Paleocene and lower Eocene sediments.

The most complete of these profiles was found in the subsurface section of Trinidad Leaseholds, Ltd., well Guayaguayare 159. This well is situated in southeast Trinidad, in the same general area as the original Lizard Springs type locality. Here, six of the nine established subdivisions are represented by cores in

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normal stratigraphic succession in the 1,200 feet of Lizard Springs penetrated in the well. The thickness of the zones varies in this well from approximately 100 feet to 500 feet.

The distribution chart (text-fig. 11) of the species of *Globigerina* and *Globorotalia* clearly shows the short ranges of most species within this age period. This short range pattern led to the present subdivision of the Lizard Springs formation into eight zones based on the stratigraphic distribution of characteristic single species or groups of species. The arenaceous facies is placed in a separate zonule. Five lower zones and the zonule are included in the lower Lizard Springs and regarded as Paleocene; the remaining three zones comprise the upper Lizard Springs, and are placed in the lower Eocene.

The lower Lizard Springs-upper Lizard Springs boundary is marked by a distinct change in both planktonic and benthonic Foraminifera. Two planktonic species become extinct in the top zone of the lower Lizard Springs and eight appear new in the bottom zone of the upper Lizard Springs. Only one *Globorotalia* species (*G. aequa* Cushman and Renz) ranges from the lower into the upper Lizard Springs. In addition, numerous benthonic forms such as the Upper Cretaceous-Paleocene *Rzehakina epigona* (Rzehak), *Clavulina aspera* var. *whitei* (Cushman and Jarvis), *Gaudryina pyramidata* Cushman, *Trochammina ruthven-murrayi* Cushman and Renz and *Bolivinoides trinitatensis* Cushman and Jarvis are not known from the upper Lizard Springs formation.

The complete change of the planktonic foraminiferal fauna between the Upper Cretaceous Guayaguayare formation and the Paleocene-lower Eocene Lizard Springs formation is not followed by the benthonic Foraminifera. According to recent investigations by J. P. Beckmann (private communication) as many as about two-thirds of the benthonic species known in the Upper Cretaceous continue into the Paleocene-lower Eocene. In cases where only benthonic Foraminifera are present, it may become difficult, therefore, to determine whether a fauna is of Upper Cretaceous or Paleocene age. Some of the earlier students on foraminiferal faunas of the Lizard Springs formation restricted their observations mainly to the benthonic part. Their preference for attributing an Upper Cretaceous age to the Lizard Springs formation is thus well understandable.

The distribution of the zones and zonule in surface and well sections of central and south Trinidad is very irregular. In the Central Range area the arenaceous facies is known as Chaudiere formation, and is strongly predominant as such. Towards the south, calcareous benthonic and planktonic Foraminifera become predominant and the arenaceous facies often remains restricted to the basal part of the formation.

The zones of the Lizard Springs formation as specified in this paper may not yet represent a continuous stratigraphic sequence. There are indications of at least two stratigraphic breaks; these will be considered in the discussion on coiling. It is still possible that such missing intervals are present in certain areas but have not yet been found.

The Lizard Springs formation consists of grey or green-grey, calcareous or noncalcareous shales. The greenish color appears to be restricted to the lower Lizard Springs. The calcium carbonate content in the calcareous facies varies from 5 to 30 percent. The percentage by weight of Foraminifera at the type localities varies from 1 to 6 percent.

Lower Lizard Springs Formation

The lower Lizard Springs formation is divided into the following zones and zonule (from bottom to top):

Rzehakina epigona Zonule

Type locality: Trinidad Petroleum Development well Moruga 15, Trinidad (coordinates N:149878 links; E:497002 links), core 4,617–37 feet.

Remarks: The zonule consists entirely of an arenaceous fauna and is found restricted to the basal part of the formation in many subsurface sections of south Trinidad. It may, in addition, represent a facies equivalent to any of the lower Lizard Springs zones. *Rzehakina epigona* (Rzehak) becomes extinct at the top of the *Globorotalia velascoensis* zone. It is a typical form throughout the Chaudiere formation of the Central Range. Thus it may be assumed that this formation is an age equivalent of the whole, or part, of the lower Lizard Springs. The *Rzehakina epigona* zonule is known to rest unconformably on the Upper Cretaceous in several places. The contact is often marked by the St. Joseph boulder bed (Bolli, 1952). In some parts of south Trinidad however, sedimentation appears to be uninterrupted between the Upper Cretaceous Guayaguayare formation and the Paleocene Lizard Springs formation. There, the *Rzehakina epigona* zonule can possibly replace parts of the Guayaguayare formation and thus represent also an Upper Cretaceous age.

Globorotalia trinidadensis Zone

Type locality: Trinidad Petroleum Development well Moruga 3, Trinidad (coordinates N:143522 links; E:504382 links), core 10,259–61 feet.

Remarks: The *Globorotalia trinidadensis* zone is characterized by the first appearance of calcareous benthonic and planktonic Foraminifera. The planktonic fauna with *Globorotalia compressa* (Plummer), *G. pseudobulloides* (Plummer), *G. trinidadensis* Bolli, new species, *Globigerina triloculinoides* Plummer and *G. daubjergensis* Bronnimann shows strong affinities to that described from Danian localities of Denmark (Bronnimann, 1952), to the basal part of the Esna shale (Buffer zone) of Egypt (Nakkady, 1951) and to parts of the Midway (e. g., Plummer, 1926).

The species of *Globigerina* and *Globorotalia* of the *Globorotalia trinidadensis* zone originate either in this zone or in a favorable facies environment contemporaneous with the underlying *Rzehakina epigona* zonule.

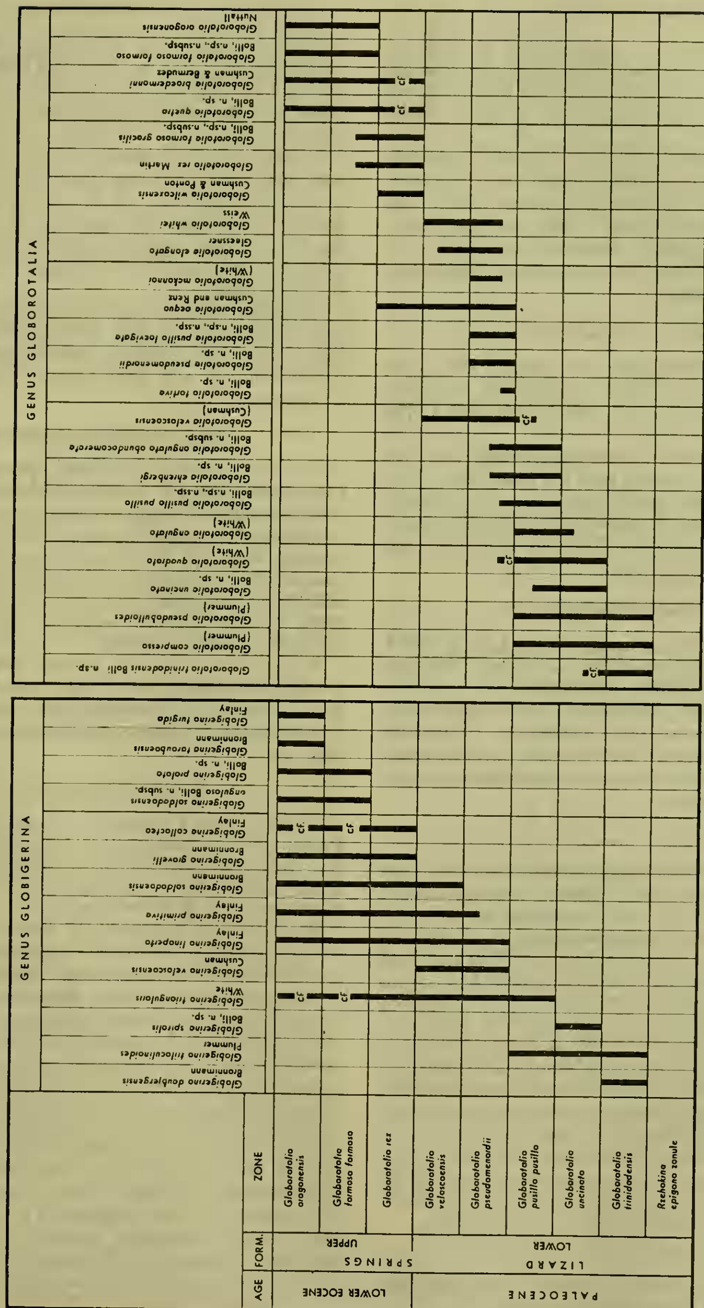

FIGURE 11.—Species distribution of *Globigerina* and *Globorotalia* in the Paleocene - lower Eocene Lizard Springs formation of Trinidad, B. W. I.

Globorotalia uncinata Zone

Type locality: On the west side of the railway track, south of the Pointe-a-Pierre Railway Station, about 500 feet from the level crossing of Station Road, Pointe-a-Pierre, Trinidad (coordinates N:259200 links; E:362900 links).

Remarks: The type locality is a small slipmass in the Oligocene-Miocene Nariva formation. The zone is characterized by *Globorotalia uncinata* Bolli, new species, and *Globigerina spiralis* Bolli, new species, in addition to the planktonic fauna of the *Globorotalia trinidadensis* zone (with the exception of *Globigerina daubjergensis* Bronnimann).

Globorotalia pusilla pusilla Zone

Type Locality: Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), cores 4,524–36 feet and 4,778–90 feet.

Remarks: *Globorotalia pusilla pusilla* Bolli, new species, new subspecies, extends into the basal part of the overlying *Globorotalia pseudomenardii* zone. *Globorotalia angulata* (White), *G. ehrenbergi* Bolli, new species, and *G. angulata hexacamerata* Bolli, new subspecies, are other typical forms of the zone.

Globorotalia pseudomenardii Zone

Type Locality: On the northeast bank of the Tank Farm at the old Club Site, Pointe-a-Pierre, Trinidad (coordinates N:256950 links; E:380000 links).

Remarks: The type locality is a small slipmass in the Oligocene-Miocene Nariva formation. A marked change in the planktonic fauna occurs at the base of this zone. Four species become extinct here and eight appear for the first time.

Globorotalia velascoensis Zone

Type Locality: The original Lizard Springs locality is maintained for this zone: Ravine Ampelu, Lizard Springs area, about 1¼ miles southeast of the road junction of the Río Claro-Guayaguayare Road (8¾ M.P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186454 links; E:556810 links), samples Rz. 282–291 (TLL 50315–16, 50503–10). For better accessibility the following cotype locality has been chosen: west side of railway track, south of the Pointe-a-Pierre Railway Station, about 650 feet from the level crossing of Station Road, Pointe-a-Pierre (coordinates N:259200 links; E:362900 links).

Remarks: *Globorotalia velascoensis* (Cushman) and *Globigerina velascoensis* Cushman become extinct at the top of the zone. Several species typical for the underlying *Globorotalia pseudomenardii* zone are absent.

Upper Lizard Springs Formation

The Upper Lizard Springs formation is divided into the following zones (from bottom to top):

Globorotalia rex Zone

Type Locality: In a left bank tributary of the Cascas River, 3,400 feet from its confluence with the Moriquite River, about 1½ miles west of the point where the Moriquite River crosses the Moruga Road (between the 14 and 14¼ M.P.). The ravine is some 650 feet in length, extending from northwest to southeast, and enters the Cascas River 250 feet downstream from the intersection of the latter with the Forest Reserve boundary. The type locality is an outcrop in the river bed of the ravine, 180 feet from its junction with the Cascas River (coordinates N:138700 links; E:435000 links).

Remarks: Eight species of *Globorotalia* and *Globigerina* occur for the first time in the *Globorotalia rex* zone. The long ranging characteristic *Globorotalia aequa* Cushman and Renz becomes extinct at the top of this zone.

Globorotalia formosa formosa Zone

Type locality: The original Lizard Springs locality is maintained for the *Globorotalia formosa formosa* zone: Ravine Ampelu, Lizard Springs area, about 1¼ miles southeast of the road junction of the Río Claro-Guayaguayare Road (8¾ M. P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, South East Trinidad (coordinates N:186505 links; E:556755 links), samples Rz. 281, 293, 296 (TLL 50314, 50512, 50515).

Remarks: *Globorotalia formosa formosa* Bolli, new species, new subspecies, *G. aragonensis* Nuttall, *Globigerina soldadoensis angulosa* Bolli, new subspecies, and *G. prolata* Bolli, new species, occur for the first time in this zone.

Globorotalia aragonensis Zone

Type locality: Outcrop on the east side of the Pointe-a-Pierre Road behind a dwelling house some 60 feet from the north end of the bridge across the Vista Bella River, San Fernando, Trinidad (coordinates N:238700 links; E:263090 links).

Remarks: The *Globorotalia aragonensis* zone which is the uppermost zone of the Lizard Springs formation is also known as Ramdat marl. In earlier publications (Cushman and Renz, 1948; Bronnimann, 1952) it was attributed to the Navet formation. Because of its close faunistic and lithologic affinities with the *Globorotalia formosa formosa* zone the Ramdat marl is now included in the upper Lizard Springs. From a point of view of lithology and fauna it is more justified to place the Lizard Springs-Navet boundary at the top of the *Globorotalia aragonensis* zone. The calcium carbonate content rises sharply from 10 to 25 percent in the Ramdat marl and other Lizard Springs zones to 50 to 70 percent in the overlying beds of the Navet formation. Many new planktonic species, e. g., *Globorotalia palmerae* Cushman and Bermudez, *G. crassata* (Cushman), and the first *Hantkenina* species appear in the Navet formation in rapid succession.

The *Globorotalia* species from the type sample (K. 2950) of "Bed 3" from Soldado Rock of Trinidad (Kugler, 1938; Cushman and Renz, 1942) have been re-investigated and determined as follows: *G. velascoensis* (Cushman), (determined as *G. wilcoxensis* var. *acuta* Toulmin by Cushman and Renz, 1942, and Bolli, 1950), *G. aequa* Cushman and Renz, *G. whitei* Weiss and *G. elongata* Glaessner. These species correspond with those characterizing the *Globorotalia velascoensis* zone which is the highest zone of the lower Lizard Springs. Cushman and Renz compare the "Bed 3" Foraminifera with Midwayan faunas from Alabama, but also point to a relationship with the Salt Mountain and the Wilcox of Ozark, Alabama. A stratigraphic position of "Bed 3" of Soldado Rock comparable with that of the uppermost lower Lizard Springs agrees also with the views of Bronnimann (1952).

Stratigraphic Correlation with Areas outside Trinidad

A limited number of samples was available to the author from areas outside Trinidad. The study of their planktonic Foraminifera allows a correlation of the Trinidad zones of the Lizard Springs formation with the widespread localities represented. Although this correlation is rather sketchy it appears to be sufficiently accurate to indicate the value of the fauna discussed for interregional correlation of the Paleocene and lower Eocene.

Samples from the Río Querecual type section of Eastern Venezuela (Hedberg, 1937; Hedberg and Pyre, 1944) show that the Upper Cretaceous part of the Vidoño shale of the Santa Anita formation=the *Globotruncana gansseri* to *Abathomphalus mayaroensis* zones of Trinidad's Guayaguayare formation and probably corresponding to Hedberg and Pyre's "*Guembelina-Siphogenerinoides* Zone") is overlain by shales which may be correlated with the *Globorotalia pseudomenardii* and *Globorotalia velascoensis* zones of the lower Lizard Springs (probably Hedberg and Pyre's "*Rzehakina-Spiroplectammina* Zone"). A gap of about 450 feet exists between the uppermost Cretaceous examined and the first Paleocene sample. It is left to additional sampling of this gap to establish the presence or absence of the *Rzehakina epigona* zonule and the *Globorotalia trinidadensis*, *Globorotalia uncinata* and *Globorotolia pusilla pusilla* zones of the lower Lizard Springs. Hedberg and Pyre's "*Gyroidina-Bulimina* Zone" possibly falls into this interval.

The facies of the higher parts of the Santa Anita formation does not appear to be favorable for the study of planktonic Foraminifera, with the exception of some layers towards the top of the formation where planktonic Foraminifera indicate a middle Eocene age.

Planktonic Foraminifera seen in a number of samples of the Midway group from the Gulf Coast area correlate well with those found in the lower Lizard Springs, especially in the *Globorotalia trinidadensis* zone. This observation is supported by publications such as that of Plummer (1926).

Available samples and published information (Cushman and Ponton, 1932; Toulmin, 1941) from the Wilcox group indicate that the planktonic Foraminifera correlate with the *Globorotalia rex* zone of the upper Lizard Spings and also with the uppermost part of the lower Lizard Springs.

Planktonic Foraminifera typical for the *Globorotalia uncinata* and *Globorotalia pusilla pusilla* zones of the lower Lizard Springs, as well as for the *Globorotalia formosa formosa* and *Globorotalia aragonensis* zones of the upper Lizard Springs have seemingly not been recorded from the Paleocene and lower Eocene of the Gulf Coast area according to the information available to the author.

The planktonic Foraminifera of a sample from the type locality of the Velasco formation of Mexico correspond with those of the *Globorotalia pseudomenardii* zone of the lower Lizard Springs. A sample from the type locality of the Aragon formation contains *Globorotalia aragonensis* but the associated fauna suggests an age slightly younger than the *Globorotalia aragonensis* zone of the upper Lizard Springs formation.

The planktonic and benthonic Foraminifera described from the Pale Greda formation of Peru indicate basal upper Lizard Springs which would place the formation into the lower Eocene, rather than Paleocene as suggested by Weiss (1955).

Two faunas have been examined from the Esna shales of Egypt. One, from the Buffer zone of Nakkady, 1951, correlates well with the *Globorotalia trinidadensis* zone of the lower Lizard Springs. The other, from Nakkady's *Globorotalia* zone, can be placed in the *Globorotalia velascoensis* zone of the lower Lizard Springs.

Planktonic forms representative of the *Globorotalia trinidadensis* and *Globorotalia pusilla pusilla* zones of the lower Lizard Springs have been seen in samples from the Paleocene of Tunisia.

Brotzen (1948) describes *Globigerina triloculinoides* Plummer, *G. pseudobulloides* Plummer, and *Globorotalia compressa* (Plummer) from the Swedish Paleocene. This would indicate an age comparable to the lower part of the lower Lizard Springs.

The planktonic Foraminifera from Danian localities of Jutland, Denmark (Bronnimann, 1952) are considered to be not younger than those from the *Globorotalia trinidadensis* zone of the lower Lizard Springs.

Finally, a Paleocene sample seen from Bavaria, Germany, contains *Globorotalia pusilla pusilla* Bolli, new species, new subspecies, *G. angulata* (White) and *G. quadrata* (White). This fauna is characteristic for the *Globorotalia pusilla pusilla* zone of the lower Lizard Springs.

Evolutionary Trends

A rapid tempo of evolution in the planktonic Foraminifera during Paleocene-Lower Eocene time is indicated by the short life ranges of many of the *Globigerina* and *Globorotalia* species described in this paper. Nine species are restricted to a single zone, fifteen to two zones, ten to three zones. Only four species have a longer range. Several groups of genetically closely related species and subspecies can be distinguished. The assumption of such genetic relationships is based on occurrences of morphologically transitional forms. Together with the evolutionary trends it is also of interest to follow the ratios of the direction of coiling. It will be shown in the following section that such ratios may be an indication of the stratigraphic position of a fauna and help to verify the genetic relation between some species and subspecies.

The dominant suite of related species begins in the *Globorotalia trinidadensis* zone with *Globorotalia trinidadensis* Bolli, new species (text-fig. 12). Based on intermediate forms it may be assumed that *Globorotalia pseudobulloides* (Plummer) which also appears in this zone, is closely related to *G. trinidadensis*. Common ancestors might be found in beds equivalent in age to those of the underlying *Rzehakina epigona* zonule. In the *Globorotalia uncinata* zone we find the zonal marker developing from *G. pseudobulloides* (for a transitional form, see pl. 17, figs. 16–18). *G. uncinata* Bolli, new species, is regarded as the ancestor of *G. angulata* (White). *G. quadrata* (White) is considered a separate branch developing from *G. trinidadensis*. At the base of the *G. pusilla pusilla* zone, *G. angulata* apparently leads through transitional forms to the long ranging *G. aequa* Cushman and Renz. Before the extinction of *G. aequa* at the end of the *G. rex* zone the two closely related *G. rex* Martin and *G. formosa gracilis* Bolli, new species, new subspecies, branch off. These two forms lead in the following zone to *G. aragonensis* [Nuttall and *G. formosa formosa* Bolli, new species, new subspecies,

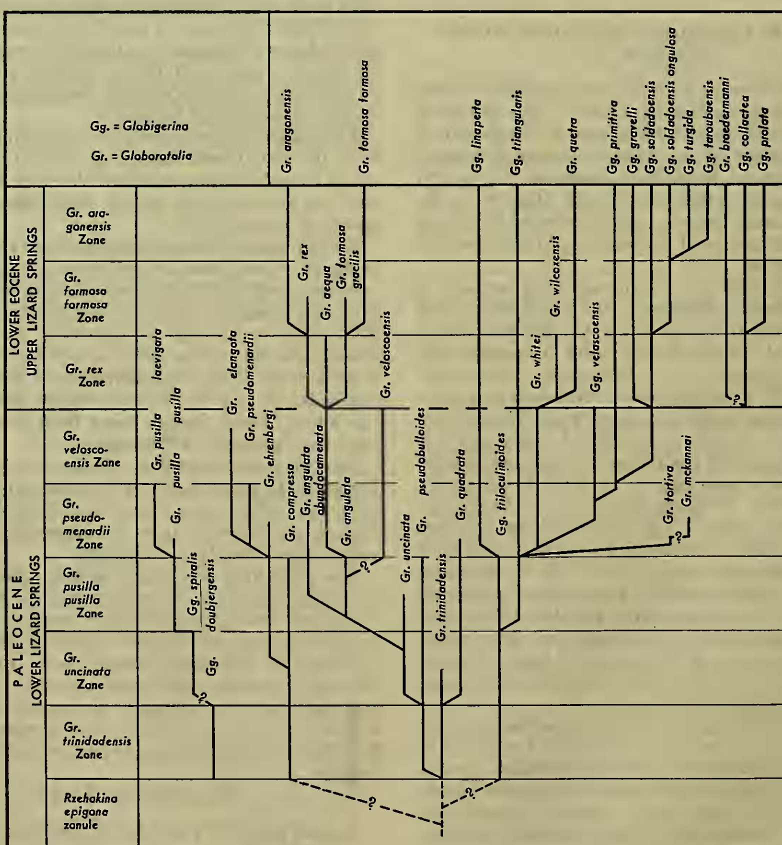

Figure 12.—Tentative evolution of *Globigerina* and *Globorotalia* species in the Paleocene - lower Eocene, Lizard Springs formation of Trinidad, B.W.I.

respectively. The last two are the end forms of the evolutionary sequence that began with *G. trinidadensis* in the lower Lizard Springs. *G. formosa formosa* becomes extinct at the close of the *G. aragonensis* zone whereas *G. aragonensis* continues without noticeable morpohological changes for a considerable time into the middle Eocene Navet formation.

Another suite of *Globorotalia* species closely related morphologically is *G. compressa* (Plummer)—*G. ehrenbergi* Bolli, new species—*G. pseudomenardii* Bolli, new species, and probably *G. elongata* Glaessner. *G. compressa* appears in the *Globorotalia trinidadensis* zone and might originate from the same stock as *G. trinidadensis*. It ranges from the *Globorotalia trinidadensis* zone into the *Globorotalia pusilla pusilla* zone where it develops into *G. ehrenbergi* by increasing its size and becoming more compressed. *G. pseudomenardii*, the descendant of *G. ehrenbergi*, becomes still more compressed and acquires a peripheral keel. Towards the end of its range this species can become of considerable size and may depart from its usual shape (see pl. 20, fig. 17). *G. elongata* which probably developed from *G. ehrenbergi-G. pseudomenardii* at the base of the *Globorotalia pseudomenardii* zone continues into the *Globorotalia velascoensis* zone where the suite becomes extinct.

Globigerina daubjergensis Bronnimann which is restricted to the *Globorotalia trinidadensis* zone shows no apparent morphologic relationship to other species of that zone. It may possibly be regarded as the ancestor of *Globigerina spiralis* Bolli, new species, which is confined to the *Globorotalia uncinata* zone. Both forms are distinctly trochospiral, however no intermediate forms were observed in the limited number of samples available from these zones.

No ancestral forms were found in the investigated sections for *Globorotalia pusilla pusilla* Bolli, new species, new subspecies. This species develops by transitions into *G. pusilla laevigata* Bolli, new species, new subspecies, of the *G. pseudomenardii* zone.

Globorotalia velascoensis (Cushman) is a distinct form characterizing the *Globorotalia pseudomenardii* and *Globorotalia velascoensis* zones. The species appears first in the *Globorotalia pusilla pusilla* zone, where it might have branched off from the *Globorotalia angulata* (White) group. Transitional forms between these species could not be clearly established in the studied sections.

Globigerina triloculinoides Plummer which first occurs in the *Globorotalia trinidadensis* zone, might have a common ancestor with *Globorotalia trinidadensis*. Specimens of *Globigerina triloculinoides* which show *Globorotalia*-like apertural characters are common throughout its range (see pl. 17, figs. 25–26). The triangular shaped *Globigerina triloculinoides* seemingly develops into the long-ranging and little-changing *G. linaperta* Finlay. Before that change, the more triangular shaped *G. triangularis* White branches off from *G. triloculinoides* at the base of the *Globorotalia pusilla pusilla* zone. *Globigerina velascoensis* Cushman, a form with a slight lateral compression of the chambers, may be regarded as a further evolutionary step from *G. triangularis*.

The laterally strongly compressed *Globorotalia tortiva* Bolli, new name, appears almost contemporaneously with *Globigerina velascoensis* at the base of the *Globorotalia pseudomenardii* zone. This short-lived species is likely to have developed from *Globigerina triangularis*. It is possible that *Globorotalia tortiva* Bolli, new name, is the ancestral form of the equally short-lived *Globorotalia mckannai* (White) which is found higher in the same zone.

Globorotalia whitei Weiss which appears in the *Globorotalia pseudomenardii* zone is another species likely to have developed from the *Globigerina triangularis-G. velascoensis* group. It is regarded as the ancestral form of *Globorotalia wilcoxensis* Cushman and Ponton and *G. quetra* Bolli, new species.

Towards the close of the *Globorotalia pseudomenardii* zone and during the *Globorotalia velascoensis* zone the first specimens of the closely related *Globigerina primitiva* Finlay and *G. soldadoensis* Bronnimann appear. Similar morphology strongly suggests that *G. primitiva* developed from *G. velascoensis*. Several species and subspecies develop in the upper Lizard Springs from *G. soldadoensis* Bronnimann, which is regarded as related to *G. primitiva*; in order of first occurrence they are *G. gravelli* Bronnimann, *G. soldadoensis angulosa* Bolli, new subspecies, and *G. turgida* Finlay. *G. taroubaensis* Bronnimann might also be related to this group, probably most closely to *G. turgida*.

Globigerina collactea (Finlay) appears first in the *Globorotalia rex* zone with no apparent ancestral forms in the underlying *Globorotalia velascoensis* zone. Such forms might however be expected in beds presumed missing between these two zones. *Globigerina prolata* Bolli, new species, is likely to have developed from *G. collactea* at the base of the *Globorotalia formosa formosa* zone.

Globorotalia broedermanni Cushman and Bermudez is another form that occurs first in the *Globorotalia rex* zone. Some intermediate specimens in the *Globorotalia rex* zone indicate a possible relationship to *Globigerina collactea*.

Direction of Coiling

Earlier observations on the direction of coiling of a number of planktonic species led to the conclusion that distinct changes in ratios occur during the evolution of many species (Bolli, 1950, 1951). During the early evolutionary stage, such a species or group of related species normally coils at random. Later, up to 90 to 100 percent of the specimens have a preference for either sinistral or dextral coiling. Once such a preference has arisen the species does not revert to random coiling any more, except in some possible gerontic stages (Bolli, 1957, p. 54). Very rapid or almost instant changes from one preferred direction of coiling to the opposite can, however, be observed in the later stages of some species, e. g., *Globorotalia menardii*

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(d'Orbigny), *G. truncatulinoides* (d'Orbigny) (Bolli, 1950; Ericson, G. Wollin and J. Wollin, 1954). Changes in the environment probably cause such sudden changes.

The coiling of a few Lizard Springs *Globorotalia* species has already been discussed in an earlier paper (Bolli, 1950). Coiling ratios for several *Globigerina* and *Globorotalia* species and groups of related species have again been followed through the now better known sections of the Lizard Springs formation. The basic picture has changed little. The coiling ratios for a hypothetical lowermost Lizard Springs given in the earlier paper have now been observed. The probable relation between *Globorotalia aequa* Cushman and Renz and *G. aragonensis* Nuttall (via *G. rex* Martin) was not realized at the time and *G. wilcoxensis* var. *acuta* Toulmin is now regarded as a synonym of *G. velascoensis* (Cushman).

Some of the more significant results are briefly discussed in the following paragraphs and shown on text-figure 13.

A genetic relationship between *Globorotalia trinidadensis* Bolli, new species, *G. pseudobulloides* (Plummer), *G. uncinata* Bolli, new species, *G. angulata* (White), *G. aequa* Cushman and Renz, *G. rex* Martin, *G. aragonensis* Nuttall, *G. formosa gracilis* Bolli, new species, new subspecies and, *G. formosa formosa* Bolli, new species, new subspecies, has been discussed in the previous section. When following the coiling ratios of these species we find that the stratigraphically older forms (*G. trinidadensis* to *G. angulata*) coil at random, thus representing the early evolutionary stage. With the transition of *G. angulata* to *G. aequa*, a very rapid change to an almost exclusively dextral coiling takes place. This preference is maintained to the point of extinction of the species at the top of the *Globorotalia rex* zone. *G. rex* and *G. formosa gracilis* which apparently branch off from the *G. aequa* group at the base of *Globorotalia rex* zone maintain the same trend. *G. aragonensis* and *G. formosa formosa* which are assumed to develop from *G. rex* and *G. formosa gracilis*, respectively, higher in the same zone, rapidly switch to sinistral coiling. The change is more rapid in *G. aragonensis* which becomes about 90 percent sinistral in the *Globorotalia aragonensis* zone. The same trend is maintained by this species until its extinction in the Navet formation. Of *G. formosa formosa*, 64 percent were found to coil sinistrally before the extinction of the species towards the top of the *Globorotalia aragonensis* zone. A sample from the probable upper part of the *Globorotalia formosa formosa* zone showed 10 percent of *G. formosa formosa* and 44 percent of *G. aragonensis* coiling sinistrally. Counts of another sample presumably from lower in the *G. formosa formosa* zone showed an almost exclusive dextral coiling for both *G. formosa formosa* and *G. aragonensis*.

Globorotalia compressa (Plummer), *G. ehrenbergi* Bolli, new species, *G. pseudomenardii* Bolli, new species, and *G. elongata* Glaessner represent another evolutionary sequence. All investigated samples showed the species coiling at random, with the exception of the topmost sample in the *Globorotalia pseudomenardii* zone. There, apparently shortly before its extinction, 80 to 85 percent of the specimens of the zonal marker were found to coil sinistrally. *G. elongata* maintains random coiling throughout its range.

Globorotalia velascoensis (Cushman) has a strong preference for sinistral coiling throughout most of its range. Only in its very early stages does the species coil at random. The very rapid change from random to sinistral coiling in *G. velascoensis* occurs concurrently with that of the *G. angulata-G. aequa* group to dextral coiling. These changes take place within a short interval in the section studied, probably within less than 100 feet. From this it may be assumed that either the change to a strongly preferred direction of coiling took place within a short time interval or the abrupt change might indicate a hiatus.

Throughout the upper Lizard Springs *Globorotalia broedermanni* Cushman and Bermudez is found to coil almost exclusively sinistrally. No random-coiling ancestral forms indicating an earlier evolutionary stage of this species were seen in the lower Lizard Springs. This suggests the presence of a hiatus between lower and upper Lizard Springs. The ancestral forms of *G. broedermanni* and *G. wilcoxensis-G. quetra* would be expected to occur in the missing beds.

Globorotalia wilcoxensis Cushman and Ponton and *G. quetra* Bolli, new species, which probably developed from *G. whitei* Weiss were found to have a strong preference for dextral coiling throughout their distribution in the upper Lizard Springs.

The above results on coiling ratios are based on approximately 25 samples, the majority of them coming from one section (Trinidad Leaseholds, Ltd., Guayaguayare well 159). For this type of investigation it would be desirable to have a greater number of samples available from well established stratigraphic sequences. The results obtained from the rather limited sources are however regarded as conclusive to warrant the presentation of the tentative picture that is discussed above and shown on text-figure 13.

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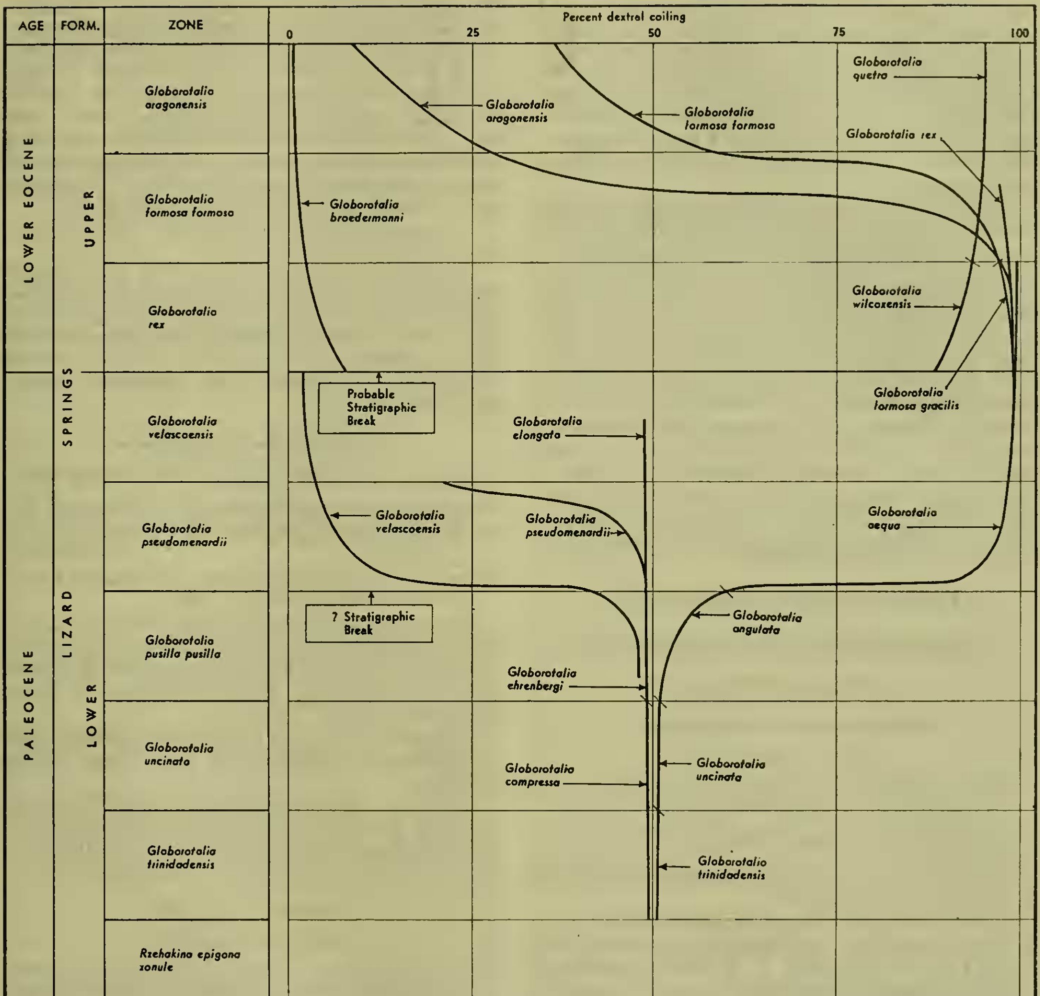

FIGURE 13.—Direction of coiling of some *Globigerina* and *Globorotalia* species in the Paleocene - lower Eocene Lizard Springs formation of Trinidad, B. W. I.

Systematic Descriptions

Fourteen species of *Globigerina* and twenty-four species of *Globorotalia* are described or listed. Most of the Lizard Springs *Globigerina* have already been accurately described by Bronnimann (1952); for these, reference is made to that publication. Although some of the *Globorotalia* species had already been described, all species, whether new or previously established, are here described in full, to present a uniform picture.

The principal difference between the genera *Globigerina* and *Globorotalia* lies in the position of the aperture. In *Globigerina* it is interiomarginal, umbilical (leading from each chamber into the open umbilicus). In *Globorotalia* it is interiomarginal, extraumbilical—umbilical (on the umbilical side of the last chamber along the suture with the first chamber of the last whorl, and leading from near the equatorial periphery into the umbilicus). Chambers in *Globigerina* are always globular or only slightly compressed; in *Globo-*

rotalia they vary from globular to strongly compressed and may have a peripheral keel. In a number of species with globular chambers, described in this paper, it became difficult to decide whether the position of the last aperture was truly umbilical or was to some degree extraumbilical—umbilical. Such transitional positions make it difficult to decide whether a species belongs to *Globigerina* or *Globorotalia* and the decision remains rather arbitrary.

The determination of the majority of the previously established *Globigerina* and *Globorotalia* species is based on a direct comparison of the Lizard Springs fauna with type material. The holotypes of the species erected by Bronnimann, Cushman and coauthors, Nuttall, Weiss and White were available to the author. Cotypes of most of the remaining species have been seen.

Globigerina finlayi, *G. hornibrooki* and *G. stainforthi*, which were erected by Bronnimann (1952) from the Lizard Springs formation, are omitted from the following species descriptions. They were found to be either exceedingly scarce, or, in the present author's opinion, not sufficiently differentiated from existing species to warrant separation. *G. finlayi* is placed in synonymy with *G. linaperta* Finlay, and *G. hornibrooki* with *G. triangularis* White, while *G. stainforthi* is regarded as close to *G. triloculinoides* Plummer.

Family Orbulinidae Schultze, 1854

Subfamily Globigerininae Carpenter, 1862

Genus Globigerina d'Orbigny, 1826

Globigerina daubjergensis Bronnimann

Plate 16, Figures 13–15

Globigerina daubjergensis Bronnimann, Eclog. Geol. Helvetiae, vol. 45 (1952), No. 2, pp. 340–341, fig. 1, 1953.

Coiling random. Largest diameter of figured hypotype 0.16 mm.

Stratigraphic range: *Globorotalia trinidadensis* zone, Lizard Springs formation.

Locality: Figured hypotype (USNM P5029) from Trinidad Leaseholds, Ltd.,-Premier Consolidated Oilfields, Ltd., well Rochard 1, Trinidad (coordinates N:148191 links; E:392552 links), sample from core 8,556–65 feet (TLL 228753).

Remarks: *Globigerina daubjergensis* Bronnimann differs from all other known early Paleocene *Globigerina* species in its small size and in the distinctly trochospiral arrangement of the chambers. *G. spiralis* Bolli, new species, displays a similar trochospiral coiling but is larger in size and possesses more chambers.

Globigerina spiralis Bolli, new species

Plate 16, Figures 16–18

Shape of test medium to high trochospiral, biconvex, spiral side distinctly convex, umbilical side less so; equatorial periphery lobate; axial periphery rounded. Wall calcareous, perforate, surface smooth. Chambers inflated, globular or slightly compressed laterally; about 15, arranged in 3 whorls; the 5–6 chambers of the last whorl increase moderately in size. Sutures on spiral side radial or slightly curved, depressed; on umbilical side radial, depressed. Umbilicus narrow, open. Apertures distinct arches with faint lips, interiomarginal, umbilical; that of last chamber in some specimens tends to an extraumbilical—umbilical position. Coiling random. Largest diameter of holotype 0.28 mm.

Stratigraphic range: *Globorotalia uncinata* zone, Lizard Springs formation.

Locality: Holotype (USNM P5030) from west side of railway track, south of the Pointe-a-Pierre railway station, about 500 feet from the level crossing of Station Road, Pointe-a-Pierre, Trinidad (coordinates N:259200 links; E:362900 links), sample KR 23575 (TLL 178894).

Remarks: See remarks under *Globigerina daubjergensis* Bronnimann.

Globigerina triloculinoides Plummer

Plate 15, Figures 18–20; and Plate 17, Figures 25–26

Globigerina triloculinoides Plummer, Univ. Texas Bull. 2644, pp. 134–135, pl. 8, figs. 10a–c, 1926.—Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 24–25, pl. 3, figs. 13–18, 1952.

Globigerina pseudotriloba White, Journ. Paleontol., vol. 2, No. 3, pp. 194–195, pl. 27, figs. 17a–b, 1928.

Coiling random in the *Globorotalia trinidadensis* and *Globorotalia uncinata* zones, but developing a preference for dextral coiling (up to 85 percent) in the *Globorotalia pusilla pusilla* zone. Largest diameter of figured hypotype 0.30 mm.

Stratigraphic range: *Globorotalia trinidadensis* zone to *Globorotalia pusilla pusilla* zone, Lizard Springs formation.

Locality: Figured hypotype (USNM P5031) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,778–90 feet (TLL 232706).

Globigerina linaperta Finlay

Plate 15, Figures 15–17

Globigerina linaperta Finlay, Trans. Proc. Roy. Soc. New Zealand, vol. 69, p. 125, pl. 13, figs. 54–57, 1939.—Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 16–17, pl. 2, figs. 7–9, 1952.

Coiling random from the *Globorotalia pseudomenardii* zone to *Globorotalia formosa formosa* zone; a slight preference for dextral coiling was noted in the *Globorotalia aragonensis* zone. Largest diameter of figured hypotype 0.42 mm.

Stratigraphic range: *Globorotalia ehrenbergi* zone to *Globorotalia aragonensis* zone, Lizard Springs formation, continuing into the Navet formation.

Locality: Figured hypotype (USNM P5032) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,212–24 feet (TLL 233002).

REMARKS: *Globigerina linaperta* Finlay is probably a descendant of *G. triloculinoides* Plummer from which it is distinguished by its larger size and less distinct flaring lip protecting the aperture.

Globigerina triangularis White

PLATE 15, FIGURES 12–14

Globigerina triangularis WHITE, Journ. Paleontol., vol. 2, No. 3, pp. 195–196, pl. 28, figs. 1a–b, 1928.
Globigerina hornibrooki BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 143, p. 15, pl. 2, figs. 4–6, 1952.

Coiling random. Largest diameter of figured hypotype 0.46 mm.

STRATIGRAPHIC RANGE: *Globorotalia pusilla pusilla* zone to *Globorotalia aragonensis* zone, Lizard Springs formation, possibly continuing into the Navet formation.

LOCALITY: Figured hypotype (USNM P5033) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,434–46 feet (TLL 233005).

REMARKS: *Globigerina triangularis* White apparently developed from *G. triloculinoides* Plummer, from which it is distinguished by the more trochospiral arrangement of its chambers and by the smaller relative size of the final chamber.

Globigerina velascoensis Cushman

PLATE 15, FIGURES 9–11

Globigerina velascoensis CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 1, p. 19, pl. 3, fig. 6, 1925.—WHITE, Journ. Paleontol., vol. 2, No. 3, p. 196, pl. 28, figs. 2a–b, 1928.

Shape of test low trochospiral, spiral side often slightly concave, umbilical side strongly inflated; equatorial periphery strongly lobate; axial periphery rounded. Wall calcareous, perforate, surface smooth. Chambers inflated, subglobular, slightly compressed laterally, about 10, arranged in 2½ whorls, the 4 chambers of the last whorl increasing rapidly in size. Sutures on spiral side oblique, depressed; on umbilical side radial, depressed. Umbilicus narrow, partly covered by the lip of the last chamber. Apertures low arches, with distinct lips; interiomarginal, umbilical; the aperture of the ultimate chamber often tends to an extraumbilical-umbilical position. Coiling random. Largest diameter of figured hypotype 0.33 mm.

STRATIGRAPHIC RANGE: *Globorotalia pseudomenardii* zone to *Globorotalia velascoensis* zone, Lizard Springs formation.

LOCALITY: Figured hypotype (USNM P5034) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,324–30 feet (TLL 233004).

REMARKS: *Globigerina velascoensis* Cushman apparently developed from *G. triangularis* White, from which it is distinguished by having the chambers of the last whorl slightly compressed laterally. Cushman's holotype of *G. velascoensis* is a poorly preserved and somewhat deformed specimen. The Lizard Springs types compare well with those of White (1928).

Globigerina primitiva Finlay

PLATE 15, FIGURES 6–8

Globigerina primitiva FINLAY, New Zealand Journ. Sci. Tech., vol. 28, No. 5, p. 291, pl. 8, figs. 129–134, 1947.—BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 11–12, pl. 1, figs. 10–12, 1952.

Coiling random. Largest diameter of figured hypotype 0.37 mm.

STRATIGRAPHIC RANGE: *Globorotalia pseudomenardii* zone to *Globorotalia aragonensis* zone, Lizard Springs formation, continues into the Navet formation.

LOCALITY: Figured hypotype (USNM P5035) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 3,707–13 feet (TLL 232994).

REMARKS: *Globigerina primitiva* Finlay probably developed from *G. velascoensis* Cushman, from which it is distinguished mainly by its spinose surface.

Globigerina soldadoensis Bronnimann

PLATE 16, FIGURES 7–12

Globigerina soldadoensis BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 9–11, pl. 1, figs. 1–9, 1952.

Coiling random. Largest diameter of figured hypotype 0.55 mm.

STRATIGRAPHIC RANGE: *Globorotalia velascoensis* zone to *Globorotalia aragonensis* zone, Lizard Springs formation, continuing into the Navet formation.

LOCALITY: Figured hypotype (USNM P5036) from Ravine Ampelu, Lizard Springs area, about 1¼ miles southeast of the road junction of the Río Claro–Guayaguayare Road (8¾ M. P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample Rz. 293 (TLL 50512).

REMARKS: *Globigerina soldadoensis* Bronnimann is closely related to *G. primitiva* Finlay, from which it is distinguished mainly by its larger size and greater number of chambers in the final whorl.

Globigerina soldadoensis angulosa Bolli, new subspecies

PLATE 16, FIGURES 4–6

Shape of test low trochospiral, spiral side slightly convex to flat, umbilical side strongly inflated; equatorial periphery distinctly lobate; axial periphery subangular. Wall calcareous, perforate, distinctly spinose. Chambers subangular, inflated; about 12, arranged in 2½ whorls, the 5 chambers of the last whorl increasing fairly rapidly in size. Sutures on spiral side oblique, depressed; on umbilical side radial, depressed. Umbilicus medium sized, open. Apertures low arches; interiomarginal-umbilical. Coiling random. Largest diameter of holotype 0.57 mm.

STRATIGRAPHIC RANGE: *Globorotalia formosa formosa* zone to *Globorotalia aragonensis* zone.

LOCALITY: Holotype (USNM P5037) from Ravine Ampelu, Lizard Springs area, about 1¼ mile southeast of the road junction of the Río Claro–Guayaguayare Road (8¾ M. P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample Rz. 293 (TLL 50512).

Remarks: *Globigerina soldadoensis angulosa* Bolli, new subspecies, differs from *G. soldadoensis* Bronnimann in the more angular shape of the chambers. It also has a more restricted stratigraphic range.

Globigerina gravelli Bronnimann

Plate 16, Figures 1–3

Globigerina gravelli Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 12–13, pl. 1, figs. 16–18, 1952.

Coiling random. Largest diameter of figured hypotype 0.47 mm.

Stratigraphic range: *Globorotalia rex* zone to *Globorotalia aragonensis* zone, Lizard Springs formation.

Locality: Figured hypotype (USNM P5038) from Ravine Ampelu, Lizard Springs area, about 1¼ miles southeast of the road junction of the Río Claro–Guayaguayare Road (8¾ M. P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links E:556755 links), sample Rz. 293 (TLL 50512).

Remarks: *Globigerina gravelli* Bronnimann is closely related to the spinose *G. primitiva* Finlay-*G. soldadoensis* Bronnimann group, from which it is distinguished by its larger size and greater number of chambers in the final whorl.

Globigerina collactea (Finlay)

Plate 15, Figures 21–23

Globorotalia collactea Finlay, Trans. Proc. Roy. Soc. New Zealand, vol. 69, p. 37, pl. 29, figs. 164–165, 1939.

Globigerina collactea (Finlay), Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 13–14, pl. 1, figs. 13–15, 1952.

Coiling random. Largest diameter of figured hypotype 0.35 mm.

Stratigraphic range: *Globorotalia rex* zone to *Globorotalia aragonensis* zone, Lizard Springs formation, continuing into the Navet formation.

Locality: Figured hypotype (USNM P5039) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core, 3,707–13 feet (TLL 232994).

Remarks: Some doubt exists as to the generic position of this species. Finlay (1939) originally described it as a *Globorotalia*. Because of the umbilical position of the apertures, Bronnimann (1952) removed it to *Globigerina*. The apertures of the specimens examined are usually umbilical, though a slight shifting of the aperture of the ultimate chamber towards an extra-umbilical-umbilical position is often noted.

Globigerina prolata Bolli, new species

Plate 15, Figures 24–26

Globigerina pseudobulloides Plummer, Bronnimann (not Plummer, 1926) Bull. Amer. Paleontol., vol. 34, No. 143, pp. 21–23, pl. 3, figs. 7–9, 1952.

Shape of test low trochospiral, biconvex. Equatorial periphery elongate, distinctly lobate. Axial periphery rounded. Wall calcareous, perforate, surface smooth. Chambers inflated globular to slightly compressed; about 12, arranged in 2½ whorls, the 4–5 chambers of the last whorl increasing rapidly in size. Sutures on spiral side radial or slightly oblique, depressed; on umbilical side radial, depressed. Umbilicus fairly wide, open. Apertures distinct arches, interiomarginal, umbilical; in some specimens the aperture of the last chamber tends to become extraumbilical-umbilical in position. Coiling in two-thirds of the specimens counted in the *Globorotalia aragonensis* zone, sinistral. Largest diameter of holotype 0.40 mm.

Stratigraphic range: *Globorotalia formosa formosa* and *Globorotalia aragonensis* zones, Lizard Springs formation; continuing into the Navet formation.

Locality: Holotype (USNM P5040) from Ravine Ampelu, Lizard Springs area, about 1¼ mile southeast of the road junction of the Río Claro—Guayaguayare Road (8¾ M.P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample Rz. 281 (TLL 50314).

Remarks: *Globigerina prolata* Bolli, new species, probably branched off from *G. collactea* Finlay in the *Globorotalia rex* zone. It became fairly common in the *Globorotalia formosa formosa* and *Globorotalia aragonensis* zones. Bronnimann (1952) figured and described this species as *Globigerina pseudobulloides* Plummer. Because of the interiomarginal, extraumbilical-umbilical position of its apertures, *pseudobulloides* is now placed in *Globorotalia*. *Globigerina prolata* differs from *Globorotalia pseudobulloides* in the umbilical position of the apertures, absence of a flaring lip in the last chamber, and more trochospiral arrangement of the chambers. Also it has a distinctly different stratigraphic range. *Globorotalia pseudobulloides* is restricted to the Paleocene (*Globorotalia trinidadensis* to the *Globorotalia pusilla pusilla* zones) and *Globigerina prolata* to the lower Eocene (*Globorotalia rex* to the *Globorotalia aragonensis* zones).

Globigerina taroubaensis Bronnimann

Plate 15, Figures 1–2

Globigerina taroubaensis Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 18–19, pl. 2, figs. 16–18, 1952.

Largest diameter of figured hypotype 0.27 mm.

Stratigaphic range: *Globorotalia aragonensis* zone, Lizard Springs formation, continuing into the Navet formation.

LOCALITY: Figured hypotype (USNM P5041) from outcrop on the east side of the Pointe-a-Pierre Road behind a dwelling some 60 feet from the north end of the bridge across the Vista Bella River, San Fernando, Trinidad (coordinates N: 238700 links; E: 363090 links), sample Bo. 112 (TLL 137688).

Globigerina turgida Finlay

PLATE 15, FIGURES 3–5

Globigerina turgida FINLAY, Trans. Proc. Roy. Soc. New Zealand, vol. 69, p. 125, 1939.—BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 143, pp. 19–21, pl. 3, figs. 1–3, 1952.

Largest diameter of figured hypotype 0.43 mm.

STRATIGRAPHIC RANGE: *Globorotalia aragonensis* zone, Lizard Springs formation, continuing into the Navet formation.

LOCALITY: Figured hypotype (USNM P5042) from outcrop on the east side of the Pointe-a-Pierre Road behind a dwelling some 60 feet from the north end of the bridge across the Vista Bella River, San Fernando, Trinidad (coordinates N: 238700 links; E: 363090 links), sample Bo. 112 (TLL 137688).

Family Globorotaliidae Cushman, 1927

Genus Globorotalia Cushman, 1927

Globorotalia pseudobulloides (Plummer)

PLATE 17, FIGURES 19–21

Globigerina pseudobulloides PLUMMER, Univ. Texas Bull. 2644, pp. 133–134, pl. 8, figs. 9a–c, 1926.
Globigerina cretacea d'Orbigny, WHITE, Journ. Paleontol., vol. 2, No. 3, pp. 193–194, pl. 27, figs. 15a–b, 1928.

Shape of test very low trochospiral, biconvex, moderately compressed. Equatorial periphery lobate. Axial periphery rounded. Wall calcareous, perforate, surface smooth. Chambers moderately compressed; 12–15, arranged in 2–2½ whorls. The 5 chambers of the last whorl increase fairly rapidly in size. Sutures on spiral side curved, less so in the last chambers, depressed; on umbilical side radial, depressed. Umbilicus fairly narrow, open. Aperture a low arch with a lip; interiomarginal, extraumbilical-umbilical. Coiling random in the *Globorotalia trinidadensis* and *Globorotalia uncinata* zones. A preference for dextral coiling (up to 75 percent) develops in the *Globorotalia pusilla pusilla* zone. Largest diameter of figured hypotype 0.35 mm.

STRATIGRAPHIC RANGE: *Globorotalia trinidadensis* zone to *Globorotalia pusilla pusilla* zone, Lizard Springs formation.

LOCALITY: Figured hypotype (USNM P5043) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,524–36 feet (TLL 232705).

REMARKS: Because of the interiomarginal, extra-umbilical-umbilical position of the aperture, *pseudobulloides* is removed from *Globigerina* to *Globorotalia*. The *Globigerina pseudobulloides* described and figured by Bronnimann (1952) from the upper Lizard Springs is not identical with Plummer's form, but belongs to *Globigerina prolata* Bolli, new species.

Globorotalia trinidadensis Bolli, new species

PLATE 16, FIGURES 19–23

Shape of test very low trochospiral, inflated; equatorial periphery lobate; axial periphery rounded. Wall calcareous, perforate, surface smooth, in early chambers often slightly rugose. Chambers globular; 14–18, arranged in 2–2½ whorls, the 5–7 chambers of the last whorl increasing slowly in size. Sutures on spiral side radial, depressed; on umbilical side radial, depressed. Umbilicus fairly wide, open. Aperture a low arch, with a thin, liplike flap in well preserved specimens; interiomarginal, extraumbilical-umbilical. Coiling random. Largest diameters of figured types 0.40–0.43 mm.

STRATIGRAPHIC RANGE: *Globigerina trinidadensis* zone to *Globorotalia uncinata* zone, Lizard Springs formation.

LOCALITY: Holotype (USNM P5044) and paratypes (USNM P5045 and P5046) from Trinidad Petroleum Development well Moruga 3, Trinidad (coordinates N:143522 links; E:504382 links), sample from core 10,259–10,261 feet (TLL 192632).

REMARKS: *Globorotalia trinidadensis* Bolli, new species, differs from *G. pseudobulloides* (Plummer) in its larger size and in having more chambers in the final whorl. Early chambers often show a rugose surface.

Globorotalia quadrata (White)

PLATE 17, FIGURES 22–24

Globigerina quadrata WHITE, Journ. Paleontol, vol. 2, No. 3, p. 195, pl. 27, figs. 18a–b, 1928.

Shape of test very low trochospiral, spiral side commonly slightly concave, umbilical side inflated; equatorial periphery lobate, quadrangular; axial periphery rounded. Wall calcareous, perforate, surface smooth, early chambers finely cancellate. Chambers inflated, globular to slightly compressed laterally; about 10–12, arranged in 2½ whorls, the 4–5 chambers of last whorl increasing rapidly in size; ultimate chamber commonly slightly smaller than penultimate. Sutures on spiral side radial, depressed; on umbilical side: radial, depressed. Umbilicus fairly wide, open. Aperture a low arch; interiomarginal, extraumbilical—umbilical. Coiling random. Largest diameter of figured hypotype 0.42 mm.

STRATIGRAPHIC RANGE: *Globorotalia uncinata* zone to *Globorotalia pseudomenardii* zone, Lizard Springs formation.

LOCALITY: Figured hypotype (USNM P5047) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E554095 links), sample from core 4,524–36 feet (TLL 232705).

REMARKS: Because of the interiomarginal, extra-umbilical—umbilical position of the aperture, *quadrata* is removed from *Globigerina* to *Globorotalia*. The species is morphologically closely related to *Globorotalia trinidadensis* Bolli, new species, from which it differs in having fewer chambers in the final whorl.

Globorotalia uncinata Bolli, new species

Plate 17, Figures 13–15

Shape of test low trochospiral, spiral side almost flat or slightly convex, umbilical side distinctly convex; equatorial periphery distinctly lobate; axial periphery rounded to subangular. Wall calcareous, perforate, surface finely spinose. Chambers subangular, inflated, laterally compressed; 12–15, arranged in about 2½ whorls, the 5–6 chambers of the last whorl increasing moderately in size. Sutures on spiral side strongly curved, depressed; on umbilical side radial, depressed. Umbilicus fairly narrow, deep, open. Aperture a low arch; interiomarginal, extraumbilical—umbilical. Coiling random. Largest diameter of holotype 0.35 mm.

Stratigraphic range: *Globorotalia uncinata* zone to *Globorotalia pusilla pusilla* zone, Lizard Springs formation.

Locality: Holotype (USNM P5048) from west side of railway track, south of the Pointe-a-Pierre Railway Station, about 500 feet from the level crossing of Station Road, Pointe-a-Pierre, Trinidad (coordinates N:259200 links; E:362900 links), sample K.R. 23575 (TLL 178894).

Remarks: *Globorotalia uncinata* Bolli, new species, differs from the related *G. pseudobulloides* (Plummer) in having subangular, laterally distinctly truncated chambers and more strongly curved sutures on the spiral side. An intermediate specimen is shown on plate 17, figures 16–18 (USNM P5075). *Globorotalia uncinata* is regarded as the ancester of *Globorotalia angulata* (White). A transitional form between these two species is shown on plate 17, figures 10–12 (USNM P5074).

Globorotalia angulata (White)

Plate 17, Figures 7–9

Globigerina angulata White, Journ. Paleontol., vol. 2, No. 3, pp. 191–92, pl. 27, figs. 13a–c, 1928.

Shape of test very low trochospiral, spiral side almost flat, umbilical side distinctly convex; equatorial periphery distinctly lobate; axial periphery acute, ornamented with minute spines in well preserved specimens. Wall calcareous, perforate, finely spinose, especially the umbilical side. Chambers angular, inflated; 12–15, arranged in 2½–3 whorls, the 5 chambers of the last whorl increasing rapidly in size. Sutures on spiral side strongly curved, slightly depressed; on umbilical side radial, strongly depressed. Umbilicus narrow, deep, open. Aperture a narrow slit; interiomarginal, extraumbilical—umbilical. Coiling random. Largest diameter of figured hypotype 0.41 mm.

Stratigraphic range: Upper part of *Globorotalia uncinata* zone to *Globorotalia pusilla pusilla* zone.

Locality: Figured hypotype (USNM P5049) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,524–36 feet (TLL 232705).

Remarks: *Globorotalia angulata* (White) differs from the ancestral *G. uncinata* Bolli, new species, in having subangular chambers and an acute periphery. *G. angulata* is regarded as the ancestor of *G. aequa* Cushman and Renz. It is further closely related to *G. angulata abundocamerata* Bolli, new subspecies.

Globorotalia angulata abundocamerata Bolli, new subspecies

Plate 17, Figures 4–6

Shape of test very low trochospiral, spiral side almost flat, inner whorl occasionally slightly raised; umbilical side strongly convex; equatorial periphery slightly lobate, almost circular; axial periphery subacute to acute without distinct keel. Wall calcareous, perforate, surface finely spinose. Chambers subangular, inflated; 14–18, arranged in 2–2¼ whorls, the 6–7 chambers of the last whorl increasing slowly in size. Sutures on spiral side curved, slightly depressed; on umbilical side radial, depressed. Umbilicus narrow, deep, open. Aperture a narrow slit; interiomarginal, extraumbilical—umbilical. Coiling random. Largest diameter of holotype 0.4 mm.

Stratigraphic range: *Globorotalia pusilla pusilla* zone to lower part of *Globorotalia pseudomenardii* zone, Lizard Springs formation.

Locality: Holotype (USNM P5050) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,524–36 feet (TLL 232705).

Remarks: *G. angulata abundocamerata* Bolli, new subspecies, is a multichambered form of *G. angulata* (White) with a slightly different stratigraphic range.

Globorotalia aequa Cushman and Renz

Plate 17, Figures 1–3; Plate 18, Figures 13–15

Globorotalia crassata var. *aequa* Cushman and Renz, Contr. Cushman Lab. Foram. Res., vol. 18, p. 12, pl. 3, figs. 3a–c, 1942.

Globorotalia lacerti Cushman and Renz, Cushman Lab. Foram. Res., Spec. Publ. 18, p. 47, pl. 8, figs. 11, 12, 1946.

Shape of test. Very low trochospiral, spiral side flat to slightly convex, umbilical side strongly convex; equatorial periphery lobate; axial periphery acute, faint keel ornamented with spines occasionally observed. Wall calcareous, perforate, surface covered with fine spines in well preserved specimens. Chambers angular, inflated; about 10–12, arranged in 2½ whorls; the 3–4 chambers of the last whorl increase rapidly in size. The last chamber may represent almost 50 percent of the surface of the test. Sutures on spiral side strongly curved, slightly depressed; on umbilical side radial, distinctly depressed. Umbilicus narrow, deep, open. Aperture a low arch; interiomarginal, extraumbilical-umbilical. Coiling over 90 percent dextral. Largest diameter of figured hypotypes 0.40 mm.

Stratigraphic range: *Globorotalia pseudomenardii* zone to *Globorotalia rex* zone, Lizard Springs formation.

LOCALITY: Figured hypotypes (USNM P5051 and P5052) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 3,813–25 feet (TLL 232995).

REMARKS: No close morphologic or stratigraphic connection is evident between *Globorotalia aequa* Cushman and Renz and the coarsely spinose *G. crassata* (Cushman) from the middle to upper Eocene. Specific rank is therefore given to *G. aequa*. It is distinguished from the related *G. angulata* (White) by having a more spinose surface, a relatively large ultimate chamber and in a distinct preference for dextral coiling. A comparison of the holotypes of *G. aequa* and *G. lacerti* Cushman and Renz clearly indicates that the latter is a junior synonym. *G. aequa* is regarded as the ancestor of *G. rex* Martin and *G. formosa gracilis* Bolli, new species, new subspecies.

Globorotalia rex Martin

PLATE 18, FIGURES 10–12

Globorotalia rex MARTIN, Stanford Univ. Publ., Univ. Ser., Geol. Sci., vol. 3, No. 3, p. 117, pl. 8, fig. 2, 1943.

Globorotalia simulatilis (Schwager), LE ROY (not Schwager, 1893), Geol. Soc. Amer., Mem. 54, pp. 32–33, pl. 9, figs. 1–3, 1953.

Shape of test, very low trochospiral, spiral side flat or slightly convex, umbilical side strongly convex; equatorial periphery lobate; axial periphery angular with distinct peripheral keel, often ornamented with spines. Wall calcareous, perforate, surface coarsely spinose. Chambers angular, inflated; about 12, arranged in 2–2½ whorls, the 4–5 chambers of the last whorl increasing rapidly in size. Sutures on dorsal side strongly curved; on umbilical side radial, depressed. Umbilicus narrow, deep, open. Aperture a low arch; interiomarginal, extraumbilical-umbilical. Coiling between 90 and 100 percent dextral. Largest diameter of figured hypotype 0.56 mm.

STRATIGRAPHIC RANGE: *Globorotalia rex* zone to *Globorotalia formosa formosa* zone, Lizard Springs formation.

LOCALITY: Figured hypotype (USNM P5053) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 3,707–13 feet (TLL 232994).

REMARKS: *Globorotalia rex* Martin differs from the related *G. aequa* Cushman and Renz in being more robust and in having a distinct thick peripheral keel. *G. rex* is regarded as the ancestor of *G. aragonensis* Nuttall.

Globorotalia aragonensis Nuttall

PLATE 18, FIGURES 7–9

Globorotalia aragonensis NUTTALL, Journ. Paleontol., vol. 4, No. 3, p. 288, pl. 24, figs. 6–8, 10, 11, 1930.—CUSHMAN and RENZ, Cushman Lab. Foram. Res., Spec. Publ. 24, p. 40, pl. 8, figs. 1, 2, 1948.—CUSHMAN and BERMUDEZ, Contr. Cushman Lab. Foram. Res., vol. 25, pt. 2, pp. 38, 39, pl. 7, figs. 13–15, 1949.

Shape of test very low trochospiral; spiral side almost flat or slightly convex, umbilical side strongly convex and slightly inflated; equatorial periphery nearly circular; axial periphery angular with keel, which is ornamented with small spines in well preserved specimens. Wall calcareous, perforate; surface, especially the umbilical side, rugose or with short, thick spines. Chambers angular, inflated; 15–18, arranged in about 3 whorls; the 6–7 chambers of the last whorl increasing slowly in size. Sutures on spiral side curved, often slightly raised and beaded; on umbilical side radial, slightly depressed. Umbilicus narrow, deep, open. Aperture a low arch; interiomarginal, extraumbilical-umbilical. Coiling preponderantly dextral in the lower part of the *Globorotalia formosa formosa* zone (over 90 percent); in its upper part reversing to a strongly predominant sinistral coiling in the *Globorotalia aragonensis* zone (about 90 percent). Largest diameter of figured hypotype 0.55 mm.

STRATIGRAPHIC RANGE: *Globorotalia formosa formosa* zone to *Globorotalia aragonensis* zone; continuing into the Navet formation.

LOCALITY: Figured hypotype (USNM P5054) from Ravine Ampelu, Lizard Springs area, about 1¼ mile southeast of the road junction of the Río Claro—Guayaguayare Road (8¾ M.P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample KWB 6972 (TLL 102301).

REMARKS: *Globorotalia aragonensis* Nuttall differs from the ancestral *G. rex* Martin in having a more compact test, less lobate periphery, stronger peripheral keel, a greater number of chambers, and a strong preference for sinistral coiling in the younger specimens.

Globorotalia formosa gracilis Bolli, new species, new subspecies

PLATE 18, FIGURES 4–6

Shape of test very low trochospiral, spiral side almost flat or slightly convex, umbilical side distinctly convex; equatorial periphery lobate: axial periphery angular with a faint keel ornamented with spines. Wall calcareous, perforate, surface distinctly spinose. Chambers angular, inflated; about 12, arranged in 2½–3 whorls, the 5–6 chambers of the last whorl increasing rapidly in size. Sutures on dorsal side slightly curved to oblique, slightly depressed; on umbilical side radial, distinctly depressed. Umbilicus fairly narrow, deep, open. Aperture a low arch; interiomarginal, extraumbilical-umbilical. Coiling between 90 and 100 percent dextral. Largest diameter of holotype 0.50 mm.

STRATIGRAPHIC RANGE: *Globorotalia rex* zone to *Globorotalia formosa formosa* zone, Lizard Springs formation.

LOCALITY: Holotype (USNM P5055) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 3,707–13 feet (TLL 232994).

REMARKS: *Globorotalia formosa gracilis* Bolli, new species, new subspecies, differs from the related *G. aequa*

Cushman and Renz in possessing a more distinct but thinner peripheral keel and more chambers in the last whorl. *G. formosa gracilis* is regarded as the ancestor of *G. formosa formosa* Bolli, new species, new subspecies.

Globorotalia formosa formosa Bolli, new species, new subspecies

Plate 18, Figures 1–3

Globorotalia velascoensis (Cushman), Cushman and Renz (not Cushman, 1925), Cushman Lab. Foram. Res., Spec. Publ. 18, p. 47, pl. 8, figs. 13, 14, 1946.

Shape of test very low trochospiral, spiral side almost flat, inner whorls occasionally slightly raised, umbilical side strongly convex; equatorial periphery slightly lobate, nearly circular; axial periphery angular with pronounced keel which is ornamented with spines in well preserved specimens. Wall calcareous, perforate, surface finely to distinctly spinose, especially on the umbilical side. Chambers angular, inflated; 15–18, arranged in about 3 whorls; the 6–8 chambers of the last whorl increasing slowly in size. Sutures on spiral side, curved; on umbilical side radial, depressed. Umbilicus fairly wide, deep, open. Aperture a low arch; interiomarginal, extraumbilical—umbilical. Coiling about 90 percent dextral in the *Globorotalia formosa formosa* zone, becoming predominantly sinistral in the *Globorotalia aragonensis* zone (up to 64 percent). Largest diameter of holotype 0.65 mm.

Stratigraphic range: *Globorotalia formosa formosa* zone and *Globorotalia aragonensis* zone, Lizard Springs formation.

Locality: Holotype (USNM P5056) from Ravine Ampelu, Lizard Springs area, about 1¼ mile southeast of the road junction of the Río Claro—Guayaguayare Road (8¾ M.P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample KWB 6972 (TLL 102301).

Remarks: *Globorotalia formosa formosa* Bolli, new species, new subspecies, differs from the related *G. formosa gracilis* Bolli, new species, new subspecies, in its more robust test, larger size, and greater number of chambers in the last whorl. *G. formosa formosa* differs from *G. aragonensis* Nuttall in its slightly larger size, more lobate periphery, greater number of chambers in the last whorl, and wider umbilicus. Also, it has a much more restricted stratigraphic range.

Globorotalia velascoensis (Cushman)

Plate 20, Figures 1–4

Pulvinulina velascoensis Cushman, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 1, p. 19, pl. 3, figs. 5a–c, 1925.

Globorotalia wilcoxensis Cushman and Ponton var. *acuta* Toulmin, Journ. Paleontol., vol. 15, No. 6, p. 608, pl. 82, figs. 6–8, 1941. For additional references see Cushman and Bermudez (1949, pp. 39, 41).

Shape of test very low trochospiral, spiral side flat; umbilical side strongly convex; in large specimens the outer wall of the chambers of the last whorl may be somewhat concave; equatorial periphery nearly circular; axial periphery angular with distinct keel which may be spinose. Wall calcareous, perforate, surface smooth, around umbilical area often rugose. Chambers angular, inflated; 12–18, arranged in 2½–3 whorls, the five chambers of the last whorl increasing moderately in size. Sutures on spiral side curved, may be slightly raised; on umbilical side radial, depressed. Umbilicus narrow and deep in small specimens, becoming wider in large specimens. Aperture a low arch; interiomarginal, extraumbilical—umbilical. Coiling random in the upper part of the *Globorotalia pusilla pusilla* zone, becoming sinistral in the *Globorotalia pseudomenardii* and *Globorotalia velascoensis* zones (about 95 percent). Largest diameter of figured hypotypes 0.49 mm. (pl. 20, figs. 1–3), and 0.27 mm. (pl. 20, fig. 4).

Stratigraphic range: *Globorotalia pusilla pusilla* zone to *Globorotalia velascoensis* zone, Lizard Springs formation.

Locality: Figured hypotypes (USNM P5057 and P5058) from Trinidad Leaseholds, Ltd., Guayaguayare well 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,324–30 feet (TLL 233004).

Remarks: *Globorotalia velascoensis* (Cushman) shows considerable variety in size and shape (especially of the umbilical area). Material studied from a Velasco shale sample of Mexico shows every intermediate stage between very small forms with a narrow umbilicus (*G. wilcoxensis* var. *acuta* Toulmin group) and large specimens with a wide umbilicus (*G. velascoensis*, s. s., group). The same has been observed throughout the life range of the species in Trinidad sections. Forms belonging to both these groups are therefore regarded as *G. velascoensis*, of which *G. wilcoxensis* var. *acuta* is a synonym. This confirms Grimsdale (1951) who regards *G. wilcoxensis* var. *acuta* as a variety of *G. velascoensis*.

Globorotalia velascoensis appears in the upper part of the *G. pusilla pusilla* zone where it may have branched off from the *G. angulata* (White) group though no clearly intermediate forms have been observed. At the end of the *G. velascoensis* zone, the species becomes extinct in Trinidad together with numerous other planktonic and benthonic forms. The author's previous assumption (Bolli, 1952) that *G. velascoensis* occurs in the upper Lizard Springs and may be regarded as the ancestor of *G. aragonensis* Nuttall is no longer maintained. *G. velascoensis* is in fact restricted to the lower Lizard Springs; the forms previously described under this name from the upper Lizard Springs are now regarded as a new species (*G. formosa gracilis* Bolli, new species, new subspecies, and *G. formosa formosa* Bolli, new species, new subspecies) probably developing from the *G. aequa* Cushman and Renz group. This is supported by the coiling ratios of the species under discussion. *G. velascoensis* coils almost exclusively sinistrally before its extinction at the end of the *Globorotalia velascoensis* zone. *G. aequa* and *G. formosa* both coil predominantly dextrally in the *Globorotalia rex* and *Globorotalia formosa formosa* zones of the upper Lizard Springs.

Globorotalia compressa (Plummer)

PLATE 20, FIGURES 21–23

Globigerina compressa PLUMMER, Univ. Texas Bull. 2644, p. 135, pl. 8, fig. 8, 1926.
Globorotalia compressa (Plummer), BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 143, p. 25, pl. 2, figs. 19–24, 1952.

Shape of test very low trochospiral, inflated; equatorial periphery distinctly lobate, slightly elongate; axial periphery subacute to acute. Wall calcareous, perforate, surface smooth. Chambers slightly compressed; 12–15, arranged in about 2½ whorls, the 4–5 chambers of the last whorl increasing fairly rapidly in size. Sutures on spiral side radial to slightly curved in early chambers, radial in last chambers, depressed; on umbilical side radial, depressed. Umbilicus fairly wide, open. Aperture a distinct arch, may have a slight lip; interiomarginal, extraumbilical-umbilical. Coiling random. Largest diameter of figured hypotype 0.23 mm.

STRATIGRAPHIC RANGE: *Globorotalia trinidadensis* zone to *Globorotalia pusilla pusilla* zone, Lizard Springs formation.

LOCALITY: Figured hypotype (USNM P5059) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,524–36 feet (TLL 232705).

REMARKS: *Globorotalia compressa* (Plummer) is the ancestor of *G. ehrenbergi* Bolli, new species, from which it is distinguished by its smaller size, less compressed chambers and absence of a peripheral keel.

Globorotalia ehrenbergi Bolli, new species

PLATE 20, FIGURES 18–20

Globorotalia membranacea (Ehrenberg), WHITE, Journ. Paleontol., vol. 2, p. 280, pl. 38, fig. 1, 1928.—CUSHMAN and BERMUDEZ, Contr. Cushman Lab. Foram. Res., vol. 25, No. 2, pp. 34, 35, pl. 6, figs. 16–18, 1949.

Shape of test low trochospiral, compressed; equatorial periphery strongly lobate; axial periphery acute, last chamber often with a faint keel. Wall calcareous, perforate, surface smooth. Chambers compressed; about 12–15, arranged in 2–3 whorls, the 5 chambers of the last whorl increasing fairly rapidly in size. Sutures on spiral side slightly curved, distinctly depressed; on umbilical side radial, depressed. Umbilicus shallow, open. Aperture a low arch, with a lip; interiomarginal, extraumbilical-umbilical. Coiling random. Largest diameter of holotype 0.28 mm.

STRATIGRAPHIC RANGE: *Globorotalia pusilla pusilla* zone to *Globorotalia pseudomenardii* zone, Lizard Springs formation.

LOCALITY: Holotype (USNM P5060) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,524–36 feet (TLL 232705).

REMARKS: *Globorotalia membranacea* (Ehrenberg) has frequently occurred in the literature (see Cushman and Bermudez, 1949, p. 34). Ehrenberg (1854) figured under *Planulina membranacea* the spiral views of 2 rotalid Foraminifera from the Cretaceous that are at least specifically different. Of these, one (pl. 26, fig. 43) could be near to a form subsequently described on several occasions as *Globorotalia membranacea* (for example, from Trinidad by Cushman and Renz, 1946). No description or depository of a holotype was given by Ehrenberg however. It is for these reasons that a new name had to be chosen for these Paleocene specimens described as *Globorotalia membranacea*. *Globorotalia ehrenbergi* developed from *Globorotalia compressa* (Plummer) and is regarded as the ancestor of *Globorotalia pseudomenardii* Bolli, new species, and possibly of *Globorotalia elongata* Glaessner.

Globorotalia pseudomenardii Bolli, new species

PLATE 20, FIGURES 14–17

?*Globorotalia pseudoscitula* GLAESSNER, Studies in Micropaleontol., Publ. Lab. Paleontol., Moscow Univ., vol. 1, pt. 1, pp. 32–33, figs. 3a–c, 1937.

Shape of test very low trochospiral, biconvex; equatorial periphery elongate, lobate, especially so in large specimens; axial periphery angular with distinct keel. Wall calcareous, perforate, surface smooth. Chambers strongly compressed; about 15, arranged in 3 whorls, the 5 chambers of the last whorl increasing rapidly in size. Sutures on spiral side strongly curved, especially so between last chambers of large specimens, depressed; on umbilical side radial, depressed. Umbilicus shallow, open. Aperture a low arch with a lip; interiomarginal, extraumbilical-umbilical. Largest diameter of holotype 0.34 mm., of figured paratype 0.66 mm.

STRATIGRAPHIC RANGE: *Globorotalia pseudomenardii* zone, Lizard Springs formation.

LOCALITY: Holotype (USNM P5061), paratype (USNM P5062) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample (holotype) from core 4,324–30 feet (TLL 233004); sample (paratype) from core 3,992–4,000 feet (TLL 233000).

REMARKS: *Globorotalia pseudomenardii* Bolli, new species, is closely related to *G. ehrenbergi* Bolli, new species, from which it apparently developed and from which it is distinguished by its less lobate periphery and less depressed spiral sutures. The name has been chosen for the resemblance to small specimens of *G. menardii* (d'Orbigny), to which it has no genetic relationship however. *G. pseudomenardii* becomes extinct at the close of the Paleocene whereas *G. menardii* appears first in the middle to upper Miocene.

Globorotalia elongata Glaessner

PLATE 20, FIGURES 11–13

Globorotalia pseudoscitula var. *elongata* GLAESSNER, Studies in Micropaleontol., Publ. Lab. Paleontol., Moscow Univ., vol. 1, pt. 1, p. 33, figs. 3d–f, 1937.

Shape of test very low trochospiral, compressed, spiral side often slightly concave, umbilical side moderately convex; equatorial periphery slightly lobate, elongate; axial periphery subacute to acute but without keel. Wall calcareous, perforate, surface smooth. Chambers moderately to strongly compressed; about 12, arranged in 2–2½ whorls, the 6 chambers of the last whorl increasing rapidly in size. Sutures on spiral side slightly curved, distinctly depressed; on umbilical side radial, distinctly depressed. Umbilicus fairly wide, open. Aperture a low arch, interiomarginal, extraumbilical-umbilical. Coiling random. Largest diameter of figured hypotype 0.33 mm.

Stratigraphic range: *Globorotalia pseudomenardii* zone to *Globorotalia velascoensis* zone, Lizard Springs formation.

Locality: Figured hypotype (USNM P5063) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,212–24 feet (TLL 233002).

Remarks: *Globorotalia elongata* Glaessner is probably closely related to the *G. ehrenbergi* Bolli, new species-*G. pseudomenardii* Bolli, new species, group. From *G. ehrenbergi*, it is distinguished by the more elongate equatorial periphery caused by the rapid increase in size of the ultimate and often also the penultimate chamber. From *G. pseudomenardii* it is distinguished by the more depressed sutures on the spiral side. The final whorl consists of 6 chambers, instead of 5 as in the other two species and the early portion is depressed in relation to the chambers of the last whorl on the spiral side.

Globorotalia pusilla pusilla Bolli, new species, new subspecies

Plate 20, Figures 8–10

Shape of test low trochospiral, biconvex, compressed; equatorial periphery nearly circular, slightly lobate; axial periphery acute to subacute. Wall calcareous, perforate, surface smooth. Chambers compressed; 12–16, arranged in 2½–3 whorls, the 5–6 chambers of the last whorl increasing moderately in size. Sutures on spiral side strongly curved, slightly depressed; on umbilical side radial, depressed. Umbilicus narrow, open. Aperture a low arch, with narrow lip; interiomarginal, extraumbilical-umbilical. Coiling random. Largest diameter of holotype 0.24 mm.

Stratigraphic range: *Globorotalia pusilla pusilla* zone and lower part *Globorotalia pseudomenardii* zone, Lizard Springs formation.

Locality: Holotype (USNM P5064) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,778–90 feet (TLL 233706).

Remarks: *Globorotalia pusilla pusilla* Bolli, new species, new subspecies, is distinguished from *G. capdevilensis* Cushman and Bermudez by its closer coiling, stronger curved sutures on the spiral side and slightly less compressed chambers. The new subspecies differs from *G. albeari* Cushman and Bermudez in having fewer chambers in the last whorl (about 5 instead of 8–10) and in being less trochospiral.

Globorotalia pusilla laevigata Bolli, new species, new subspecies

Plate 20, Figures 5–7

Shape of test low trochospiral, biconvex, compressed; equatorial periphery circular, slightly lobate; axial periphery acute, last chambers often with a faint keel. Wall calcareous, perforate, surface smooth. Chambers strongly compressed; 12–16, arranged in about 3 whorls; the 5–6 chambers of the last chamber increasing moderately in size. Sutures on spiral side strongly curved; on umbilical side radial. Umbilicus narrow, open. Aperture a low arch; interiomarginal, extra-umbilical-umbilical. Largest diameter of holotype 0.28 mm.

Stratigraphic range: *Globorotalia pseudomenardii* zone, Lizard Springs formation.

Locality: Holotype (USNM P5065) from northeast bank of Tank Farm at the old Club Site, Pointe-a-Pierre, Trinidad (coordinates N:256950 links; E:380000 links), sample K. 10832 (TLL 228674).

Remarks: *Globorotalia pusilla laevigata* Bolli, new species, new subspecies, is closely related to *G. pusilla pusilla* Bolli, new species, new subspecies, from which it develops. The subspecies *laevigata* is distinguished from the subspecies *pusilla* by its more circular outline and acute axial periphery and by its spiral sutures not being depressed.

Globorotalia tortiva Bolli, new name

Plate 19, Figures 19–21

Globigerina velascoensis var. *compressa* White, Journ. Paleontol., vol. 2, No. 3, p. 196, pl. 28, figs. 3a–b, 1928.

Shape of test very low trochospiral, spiral side almost flat, umbilical side strongly convex; equatorial periphery lobate, chambers give a quadrangular to pentagonal outline; axial periphery rounded to subangular. Wall calcareous, perforate, surface finely spinose. Chambers laterally strongly compressed; 10–12, arranged in 2–2½ whorls, the 4–4½ chambers of the last whorl increasing rapidly in size. Sutures on spiral side curved in early chambers, often straight, oblique between penultimate and ultimate chambers, depressed; on umbilical side radial or slightly curved, depressed. Umbilicus narrow, open. Aperture a high arch; interiomarginal, extraumbilical-umbilical. Coiling 85 percent dextral in the only sample investigated. Largest diameter of holotype 0.33 mm.

Stratigraphic range: Lower part of *Globorotalia pseudomenardii* zone, Lizard Springs formation.

Locality: Hypotype (USNM P5066) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,434–46 feet (TLL 233005).

Remarks: White (1928) described an identical form from Mexico under the name *Globigerina velascoensis* var. *compressa*. The interiomarginal, extraumbilical-umbilical position of the aperture places it within the genus *Globorotalia* where it becomes a homonym of *G. compressa* (Plummer). For this reason the new name *G. tortiva* is proposed. *G. tortiva* possibly branched off from *Globigerina velascoensis* which has less compressed chambers and an umbilical position of the apertures.

Globorotalia mckannai (White)

PLATE 19, FIGURES 16–18

Globigerina mckannai WHITE, Journ. Paleontol., vol. 2, No. 3, p. 194, pl. 27, figs. 16a–c, 1928.

Shape of test low trochospiral, umbilical side strongly inflated; equatorial periphery nearly circular, slightly lobate; axial periphery rounded. Wall calcareous, perforate, finely spinose. Chambers inflated, slightly compressed laterally; 12–16, arranged in 2–3 whorls, the 5–7 chambers of the last whorl increasing moderately in size. Sutures on spiral side oblique, depressed; on umbilical side, radial, depressed. Umbilicus narrow, open. Aperture a low arch; interiomarginal, extraumbilical-umbilical. Coiling random. Largest diameter of figured hypotype 0.35 mm.

STRATIGRAPHIC RANGE: Upper part of *Globorotalia pseudomenardii* zone, Lizard Springs formation.

LOCALITY: Figured hypotype (USNM P5067) from northeast bank of Tank Farm at the old Club Site, Pointe-a-Pierre, Trinidad (coordinates N:256950 links; E:380000 links), sample K. 10832 (TLL 228674).

REMARKS: The species is moved to the genus *Globorotalia* because of the interiomarginal, extraumbilical-umbilical position of the aperture. *G. mckannai* (White) is possibly related to *G. tortiva* Bolli, new name, from which it is distinguished by having more chambers in the last whorl.

Globorotalia whitei Weiss

PLATE 19, FIGURES 10–12

Globigerina crassaformis Galloway and Wissler, WHITE, Journ. Paleontol., vol. 2, No. 3, p. 193, pl. 27, figs. 14a–c, 1928.
Globorotalia whitei WEISS, Journ. Paleontol., vol. 29, No. 1, pp. 18, 19, pl. 6, figs. 1–3, 1955.

Shape of test very low trochospiral, umbilical side inflated; equatorial periphery lobate; axial periphery rounded to subacute. Wall calcareous, perforate, finely spinose. Chambers inflated, slightly compressed laterally; about 12, arranged in 2–2½ whorls, the 4–5 chambers of the last whorl increasing moderately in size. Sutures on spiral side oblique, depressed; on umbilical side radial, depressed. Umbilicus fairly narrow, open. Aperture a low arch; interiomarginal, extraumbilical-umbilical. Coiling random. Largest diameter of figured hypotype 0.33 mm.

STRATIGRAPHIC RANGE: *Globorotalia pseudomenardii* to *Globorotalia velascoensis* zone, Lizard Springs formation.

LOCALITY: Figured hypotype (USNM P5068) from Trinidad Leaseholds, Ltd., Guayaguayare well 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 4,212–24 feet (TLL 233002).

REMARKS: *Globorotalia whitei* Weiss appears to be the ancestor of *G. wilcoxensis* Cushman and Ponton. From that species it is distinguished mainly by its smaller size and less acute axial periphery.

Globorotalia wilcoxensis Cushman and Ponton

PLATE 19, FIGURES 7–9

Globorotalia wilcoxensis CUSHMAN and PONTON, Contr. Cushman Lab. Foram. Res., vol. 8, pt. 3, p. 71, pl. 9, figs. 10a–c, 1932.

Shape of test very low trochospiral, spiral side flat, occasionally slightly concave; umbilical side strongly convex and inflated; equatorial periphery lobate; axial periphery rounded, in last chambers often becoming acute. Wall calcareous, perforate, distinctly spinose. Chambers inflated, slightly compressed laterally; about 10, arranged in 2-2¼ whorls, the 4 chambers of the last whorl increasing rapidly in size, the last chamber often slightly reduced again. Sutures on spiral side oblique, depressed; on umbilical side radial, strongly depressed. Umbilicus narrow, deep, open. Aperture a low arch; interiomarginal, extraumbilical-umbilical. Coiling about 85 percent dextral. Largest diameter of hypotype 0.48 mm.

STRATIGRAPHIC RANGE: *Globorotalia rex* zone, Lizard Springs formation.

LOCALITY: Figured hypotype (USNM P5069) from Trinidad Leaseholds, Ltd., well Guayaguayare 159, Trinidad (coordinates N:151361 links; E:554095 links), sample from core 3,707–13 feet (TLL 232994).

REMARKS: *Globorotalia wilcoxensis* Cushman and Ponton is regarded as the ancestor of *G. quetra* Bolli, new species.

Globorotalia quetra Bolli, new species

PLATE 19, FIGURES 1–6

Shape of test very low trochospiral, spiral side flat or slightly concave, umbilical side strongly convex, angular; equatorial periphery strongly lobate; axial periphery subacute to acute, a spiny peripheral keel is often present in the early chambers of the last whorl; ultimate and penultimate chambers acute or rounded. Wall calcareous, perforate, distinctly spinose. Chambers angular to subangular, inflated; about 12, arranged in 2½ whorls, the 4–5 chambers of the last whorl increasing rapidly in size. Sutures on spiral side oblique or curved, depressed; on umbilical side radial, depressed. Umbilicus fairly narrow, deep, open. Aperture a low arch; interiomarginal, extraumbilical-umbilical. Coiling over 90 percent dextral in the *Globorotalia formosa formosa* and *Globorotalia aragonensis* zones. Largest diameter of holotype 0.64 mm. Largest diameter of figured paratype 0.50 mm.

STRATIGRAPHIC RANGE: *Globorotalia rex* zone to *Globorotalia aragonensis* zone, Lizard Springs formation.

LOCALITY: Holotype (USNM P5070) and figured paratype (USNM P5071) from Ravine Ampelu, Lizard Springs area, about 1¼ mile southeast of the road junction of the Río Claro—Guayaguayare Road (8¾ M.P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample Rz. 293 (TLL 50512).

REMARKS: *Globorotalia quetra* Bolli, new species, is a very characteristic form in the upper Lizard Springs, where it is especially abundant in the *Globorotalia formosa formosa* zone. By its shape it might readily be mistaken for the middle Eocene *Truncorotaloides rohri* var. *mayoensis* Bronnimann and Bermudez or for *G. topilensis* Cushman (which probably is a *Truncorotaloides*). However, *G. quetra* lacks the sutural apertures on the spiral side which are characteristic for *Truncorotaloides* while its stratigraphic range is restricted to the lower Eocene. *G. quetra* appears to be closely related to *G. wilcoxensis* Cushman and Ponton, from which it is distinguished by the distinct angular shape of its test. Intermediate forms were found in the *Globorotalia rex* zone.

Globorotalia broedermanni Cushman and Bermudez

Plate 19, Figures 13–15

Globorotalia broedermanni Cushman and Bermudez, Contr. Cushman Lab. Foram. Res., vol. 25, p. 40, pl. 7, figs. 22–24, 1949.

Shape of test biconvex, low trochospiral, moderately compressed; equatorial periphery nearly circular; axial periphery rounded to subangular. Wall calcareous, perforate, surface covered with short spines. Chambers subangular, inflated; about 12–15, arranged in 2½–3 whorls, the 5–6 chambers of the last whorl increasing slowly in size. Sutures on spiral side curved, slightly depressed between last chambers of final whorl; on umbilical side radial, slightly depressed. Umbilicus narrow, open. Aperture a low arch; interiomarginal, extraumbilical—umbilical. Coiling over 90 percent dextral. Largest diameter of hypotype 0.33 mm.

Stratigraphic range: *Globorotalia rex* zone to *Globorotalia aragonensis* zone, Lizard Springs formation; continuing into the Navet formation.

Locality: Figured hypotype (USNM P5072) from Ravine Ampelu, Lizard Springs area, about 1¼ mile southeast of the road junction of the Río Claro—Guayaguayare Road (8¾ M.P.) and the old Trinidad Central Oilfields Road leading to the abandoned Lizard Springs oilfield, southeast Trinidad (coordinates N:186505 links; E:556755 links), sample Rz. 293 (TLL 50512).

Remarks: The origin of *Globorotalia broedermanni* Cushman and Bermudez cannot be traced in the Trinidad sections. The species appears at the base of the *Globorotalia rex* zone apparently fully developed and with a strong preference for dextral coiling (indicating an advanced evolutionary stage). A marked faunistic change between the *Globorotalia rex* zone and the older *Globorotalia velascoensis* zone indicates a hiatus in the studied sections. It is in this missing interval that possible ancestral forms of *Globorotalia broedermanni* have to be sought.

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